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A Slow Response Temperature Controller

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A SLOW RESPONSE TEMPERATURE CONTROLLER

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INTRODUCTION

Precise control and measurement of temperatures is required to do many of the studies in experimental chemistry, physics, metallurgy, and geology. In the laboratory, temperatures are usually produced with resistance heaters, measured with thermocouples, and controlled with feedback circuits. These temperature controllers compare the output of the thermocouple with a reference output, and generate an error signal that is used to adjust the amount of power supplied to the furnace. Many types of furnaces and controllers are commercially manufactured; these commercial systems are excellent in most cases. However, certain types of furnace systems are very fast acting--that is, they change temperature very rapidly with changes in power. These types of systems are very difficult to control accurately with commercial controllers.

In this laboratory, we have encountered problems of temperature with piston-cylinder and internally heated pressure vessel systems. Reference 1 describes a piston-cylinder apparatus and ref. 2 describes internally heated pressure vessel systems. To overcome these problems, we have designed and tested a temperature controller which gives excellent performance with very fast acting furnaces. This paper describes the controller circuitry and its use with a piston-cylinder apparatus. The application of the circuit to other control problems is direct.

CIRCUIT DESCRIPTION

Figure 1 is a schematic of the control circuit; some pertinent construction notes are included on the figure. Two features are required to control temperature in fast acting systems:

1. Very slow response to temperature changes. R10, R11, R12 or R13 may be selected to change the gain of $IC2_A$ which changes the response time of $IC2_B$. The "capacitive feedback" across $IC2_B$ introduces a time delay into the action of $IC2_B$; this time delay changes as the capacitor charges or discharges.

2. Adjustable controller output to the Power Pak R29 is placed in series with the controller output to limit the input to a Power Pak that provides power to the load; full controller action can then be adjusted to any percentage of output necessary to maintain temperature.

To function, the circuit requires a -15V to +15V DC power supply which is not shown. The controller actuates an external power supply which supplies heater power to the furnace; it has control lines connected to ground and the connection number 16 (labeled "out"). This power supply is user supplied to match the requirements of the furnace system.

The following notes illustrate the features and basic functioning of this circuit:

1. Thermocouples. Since the controller functions on millivolt inputs, any thermocouples can be used. Two ranges (0 - 10 mv and 0 - 50 mv) are provided so that the sensitivity of the controller can be matched to the thermocouple range. SW-1 selects R4 or R5 to change the gain on the amplifier and thus the range. The temperature may be measured by connecting any commercial read-out device across points 6 and 7, and thus one thermocouple may be used for both control and measurement.

2. Adjustable response time. SW2 provides a selection of response times by changing the gain on $IC2_A$.

3. Variable output. R-29 is used to vary the output of the controller to the furnace power supply, and limits the output to the load. Consequently, 100% of the control range can be used to control any percentage of output from the Power Pak. This feature, coupled with the adjustable response time, eliminates temperature cycling.

4. Thermocouple failure. With no thermocouple output, R31 is adjusted until Q1 conducts, shorting the controller output to ground and shutting off the Power Pak output. Note that the circuit may be adjusted to act at any point of the thermocouple output. To start the controller, SW7 is held closed until any preset temperature is reached, then released; Q1 remains open unless thermocouple output drops below the preset point.

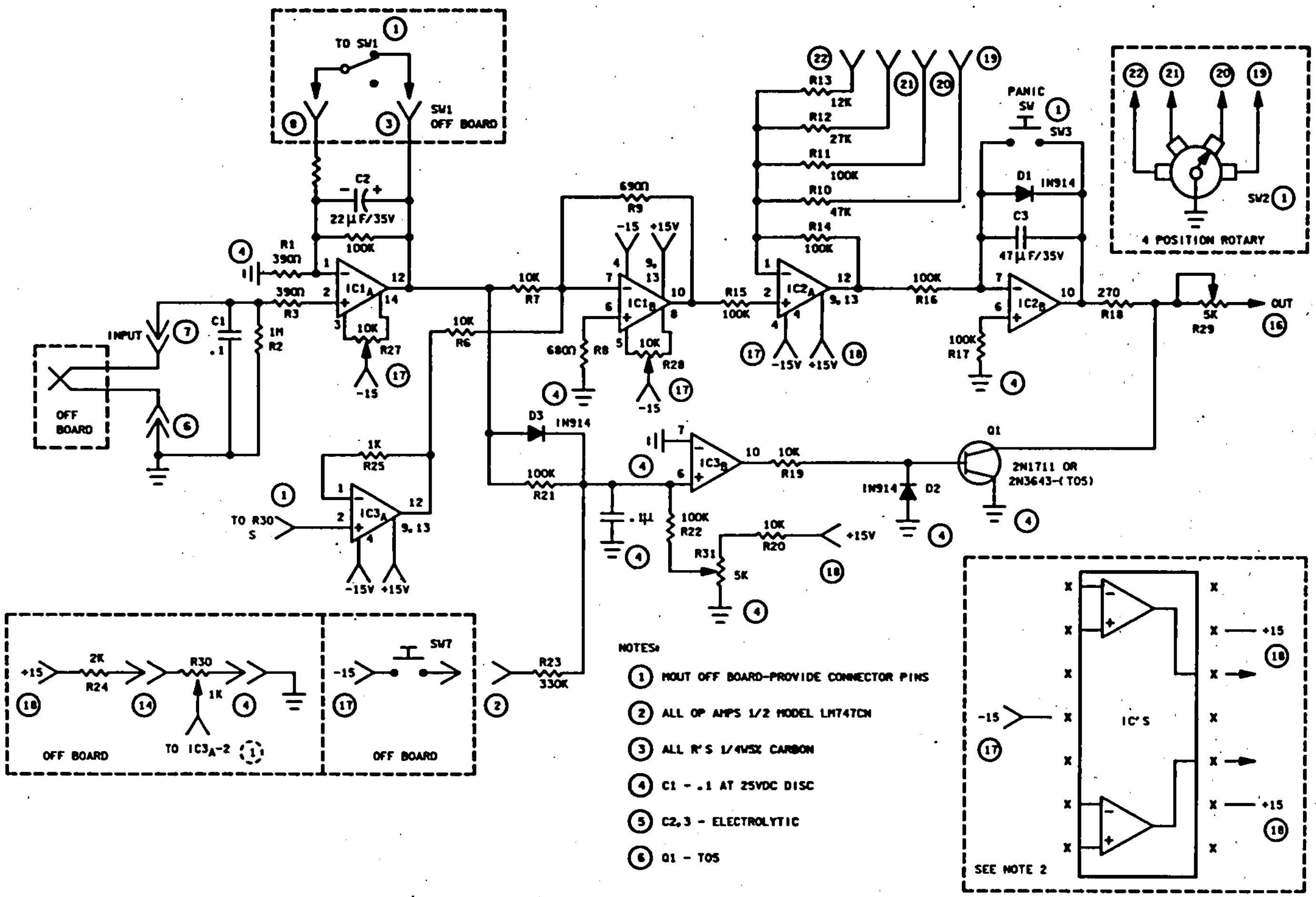
5. Slow response time. $IC2_B$, D1, and C3 provide the slow response time which is critical for controlling fast acting furnaces. SW8 is a "panic switch" to be used if overheating occurs. If depressed, C3 discharges rapidly and the controller output drops to zero. The output will then increase slowly as C3 charges.

OPERATION

After all connections are made to the furnace power system and the thermocouple break protection has been set up, R30 is increased while SW7 is depressed until the furnace temperature (as indicated by an external readout) reaches the preselected minimum temperature. SW7 is released, and the temperature is monitored for about twenty minutes to check for cycling. If any cycling is observed, SW2 is switched to adjust the response time. After the cycling has been eliminated, R30 is adjusted in small steps until the desired temperature is reached. If the desired temperature cannot be reached with R30 at full scale, R29 is adjusted until enough power is supplied to maintain the desired temperature.

CONCLUDING REMARKS

Temperature control in fast acting furnaces is difficult to achieve because the furnace temperatures change very rapidly with changes in delivered



Symbols:

IC - operational amplifier
R - resistor
C - capacitor
Q - transistor
D - diode

Notes:

1. All ICs are 1/2 of a model LM 747 CN.
2. All Rs are 1/4 w, 5% carbon.
3. Cl is 0.1 t, 25 VDC.
4. C2 and C3 are electrolytic.
5. R27, R28, R29, and R31 are board-mounted minipots.
6. R30 is a 10-turn potentiometer.
7. Q1 is TO-5.

Figure 1.- Schematic of control circuit.

power. Control requires circuits with very slow control action. The piston-cylinder apparatus is a device which requires this type of control. This circuit has been designed, built, and tested which meets these exacting requirements. It has been used to obtain control better than ±2°K for 12 hours in our systems.

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2. Holloway, J. R. (1971), Internally heated pressure vessels. Research for High Pressure and High Temperatures (Gene C. Ulmer, ed.), New York: Springer-Verlag, pp. 217-258.

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16. Abstract

The circuit diagram for a temperature controller for use with very fast-acting (low thermal mass) furnace systems is presented and its features described. The operation of the slow response temperature controller is discussed.

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